Measurement and Testing for Equality of Foreign Price and Consumer Price Index Transmission in Russia

Carlos Arnade and Stefan Osborne

Economists, Economic Research Service, United States Department of Agriculture, Washington, DC.

This paper tests for segmentation of retail meat markets in Russia before and after the financial crisis of 1998. Using monthly prices of pork and beef in 80 regions of Russia from 1994 to 1999, we measure the short-run response of regional prices to changes in foreign prices and domestic inflation. We find that changes in both foreign prices and domestic inflation have distinct impacts on the prices of these commodities in different Russian cities, indicating that the markets are segmented in the short run. An analysis of the effect of the financial crisis shows that the response to the crisis was mixed, with some regions showing more evidence of segmentation than others.

Cet article mesure le degré de segmentation des marchés de détails des viandes en Russie avant et après la crise financière de 1998. Utilisant des prix mensuels des viandes de bœuf et de porc dans quatre-vingts régions de Russie entre 1994 et 1999, nous mesurons la réponse à court-terme des prix régionaux aux changements des prix extérieurs et de l'inflation domestique. Nous trouvons que des variations des prix extérieurs comme celles de l'inflation domestique ont des impacts distincts sur les prix de ces produits dans différentes villes de la Russie; ce qui indique que les marchés de ces produits sont segmentés à court terme. Une analyse de l'effet de la crise financière montre que la réponse à la crise était mixte, avec quelques régions montrant l'évidence plus prononcée de segmentation par rapport aux autres.

INTRODUCTION

The goal of this paper is to determine if domestic Russian beef and pork markets were segmented during the transition period of the 1990s. We test for short-run market segmentation in Russia by measuring and comparing the transmission of foreign to domestic meat prices across city markets in Russia. If the transmission of foreign price changes to different city markets is not equal, then these markets must be segmented. We devise a test whose null hypothesis is that the transmission of foreign meat prices to different city markets in Russia is equal. Rejection of this hypothesis implies regional markets in Russia are segmented.

Russia is a major importer of beef, pork and poultry.[1] According to world agricultural trade 121 released by USDA's Foreign Agricultural Service, in volume terms, Russia has been the world's third largest beef importer (after the United States and Japan, with the European Union as a group coming in fourth) for the past decade and the world's second largest importer of pork (after Japan) since 1995. Russia has been the second largest poultry importer (after China) since 1994. In fact, since China is also a large poultry exporter, Russia is the world's largest net importer of poultry. The most consistent beef and pork supplier

throughout the period studied (1994–99) was the European Union, though a wide number of other countries have supplied the Russian market. In the same period, the United States was the primary poultry supplier to Russia, supplying (under normal circumstances) about 80% of all imported poultry, while the European Union supplied the rest.

The steady stream of meat imports into Russia provides a unique opportunity to measure the response of different meat markets within Russia to price shocks originating in the world market. If the reaction of prices in separate regions to outside price shocks is significantly different, that is evidence that the regional markets in Russia are not integrated. The question of whether price reforms actually led to integrated markets within Russia has been one of the major research questions in the post-reform period. An analysis of meat markets in particular will help understand one of the most important destinations for meat exports and, consequently, an important determinant of world meat prices.

Russian prices were set arbitrarily by administrative fiat before 1992. The reforms of 1992 allowed prices to vary freely, but it is not clear whether the variable Russian prices have served their function of transmitting information from one market to another (see Hayek 1945) and thus integrating the regional markets into one economy. As Russia moved toward a market economy throughout the 1990s, regional authorities at times imposed their own economic rules and trade restrictions. By the late 1990s, the twin issues of domestic market segmentation and arbitrary decision making by regional authorities became a concern to Russian policy makers at the national level as well as to private firms doing business in Russia.

Numerous authors have focused on long-run integration of post-reform Russian food markets. Collectively, they have obtained mixed results (Berkowitz and Dejong 1999; Berkowitz 1997; Gardner and Brooks 1994; Goodwin et al 1999). This paper complements the literature on Russian food market integration by focusing on the short run. Even if regional markets are integrated in the long run, economic shocks can bring about temporary distortions in regional price relationships if markets are segmented in the short run. This can have a large impact on welfare if the system is slow to return to an integrated market equilibrium. Furthermore, the frequency of structural breaks and shocks to newly emerging Russian markets means that temporary distortions in regional price relationships could have had a large impact on welfare.

An analysis of market segmentation within Russia during the late 1990s cannot ignore the 1998 financial crisis that caused a 75% nominal and 37% real depreciation in the value of the ruble by January 1999. Food imports fell significantly following the devaluation but food production remained constant.[2] One of several possible explanations that could account for this uneven response of importers and producers to the crisis is that the price shocks from the crisis were transmitted to the major urban consuming markets but not to the markets in producing regions. Therefore, we also investigate whether the crisis had an impact on price transmission to internal markets and what effect this had on short-run market segmentation.

The next section of the paper discusses the issues of Russian market segmentation and the 1998 crisis. This is followed by a brief review of the literature (Other Studies), a methodology section (Market Price Relationships and Segmentation and Our Method) and a Data section. In the Results section, we show that neither the beef nor pork markets are integrated in the short run according to the definition used in our paper. Also in the Results section, we discuss how market segmentation changed after the 1998 financial crisis. Finally, we provide concluding comments and suggestions for further research.

RUSSIAN MARKET SEGMENTATION

The emergence of strong regional governments, the weakening of the central government and worsening transportation links in the mid-1990s led to the suspicion that some of Russia's internal markets have become segmented. Specifically three reasons have been offered to explain segmentation of the agricultural market in Russia. One is that regional governors, in the name of food security, restrict the flow of food products from one administrative region to another (Berkowitz 1999; Goodwin et al 1999). The second reason is that the poor physical infrastructure impedes Russian farmers' ability to transport goods from rural to urban areas. The third reason is poorly functioning economic institutions that raise the overall transaction costs of doing business (Wehrheim et al 2000).[3]

The 1998 financial crisis is sometimes mentioned as a reason for market segmentation in Russia. However, there is considerable debate on the crisis's effect on segmentation. On the one hand, confusion over the nature of the crisis raised food security concerns and may have shocked some local officials into stockpiling food and increasing local protectionism. This reaction would reduce trade among domestic markets, leading to more domestic market segmentation (see De Masi and Koen 1996). On the other hand, as Russia's real exchange rate fell, the more favorable prices of domestic products versus imports encouraged Russia's consuming regions to purchase from Russian producing regions rather than from foreign sources.[4] The increased trade between Russia's producing and consuming regions may have increased the integration of domestic markets. Given the plausibility of either of these scenarios, it is difficult *a priori* to predict what the effect of the financial crisis had on segmentation of Russia's food markets. Therefore, we investigate whether segmentation in Russia's beef and pork markets rose or fell after the crisis.

OTHER STUDIES

Papers on market integration in Russia since 1992 have used the available price data to focus primarily on long-run market integration and have found mixed results. Gardner and Brooks (1994), using standard empirical techniques for stationary data, found that unexplained price differences between cities do not decline over time. Berkowitz et al (1998), using a longer data series (from 1992 to 1995), used cointegration analysis and found that price differences between cities declined significantly in the period studied.[5] Goodwin et al (1999) found that Russian food markets were integrated in general but that there were several regional pockets of resistance to price reform and thus segmented from the general Russian market. Berkowitz and Dejong (1999) showed that these pockets of resistance were concentrated in regions that voted for Ziuganov (the leader of the Communist party in Russia) in the 1995 presidential elections. A paper by Osborne and Liefert (2004) indicated that there are no cointegrating relationships between international meat prices and prices in cities in Russia, except in Moscow, indicating the Moscow market was segmented from the rest of the Russian economy. Loy and Weaver (1998) also found evidence of uneven domestic market integration in Russia.

Our paper adds to the literature on Russian market integration in three ways. First, we introduce a method that tests for segmentation rather than for market integration. That is, rejection of our null hypothesis implies that markets are segmented (if we do not reject the null hypothesis, it does not ensure that markets are integrated). Second, we emphasize the short run. Our test for short-run segmentation is suited to Russia since it does not rely on

assumptions about long-run integration, which, given the frequency of structural changes throughout Russia's transition, is difficult to test. Third, by using a longer time series than previous studies, we are able to examine the effect of the financial crisis of 1998 on market integration.

Another contribution of this paper, which relates to the literature on both the Russian and western economies, is that we include both the foreign price and the domestic Consumer Price Index (CPI), as well as seasonal variables, as explanatory variables. Price transmission equations often have included only one of these variables or the other (see Gardner 1975; Schwartz and Willet 1994).[6]

MARKET PRICE RELATIONSHIPS AND SEGMENTATION

To set up the test, first suppose that there exist n regions. In spatial market equilibrium, the price of good k across these regions in time $t-1$ is:

$$\left| p_{i,t-1}^k - p_{j,t-1}^k \right| = d_{ij} \qquad \text{if } q_{ij,t-1} > 0$$

and: (1)

$$\left| p_{i,t-1}^k - p_{j,t-1}^k \right| < d_{ij} \qquad \text{if } q_{ij,t-1} = 0$$

where:

q_{ij} = the volume of shipments between regions i and j, for $i, j \in \{1, 2, \ldots, n\}$ (Barret and Li 2002)
d_{ij} = the transaction cost of trading between region i and j.

Note that exploiting this relationship requires information about trade between cities, which is not available from Russia. Instead, we will make an assumption that allows us to form hypotheses about the relationship between prices in different cities regardless of the value of q_{ij}. Suppose there is a city from which all trade originates and that all cities trade with at least one other city. If markets are not segmented, then the prices in all cities will be proportional to the transaction costs relative to the originating city. For example, in the Central region of Russia, trade originates from Moscow. This allows us to specify all prices relative to the original city, which eliminates all inequalities (see Appendix).

Given that all inequalities have been eliminated, we can redefine the equilibrium equation in a way that will facilitate joint comparison of all cities. We also assume that transaction costs are a fraction of price, rather than an additive cost.[7]

Define a region as integrated if there is an originating city, so that all prices can be expressed in terms of the originating city price. The equilibrium condition can then be written as:

$$p_{1t-1}^k = p_{2t-1}^k \left(1 + \delta_2\right) = p_{3t-1}^k \left(1 + \delta_3\right) = \ldots = p_{nt-1}^k \left(1 + \delta_n\right) \qquad (2)$$

Note that the equilibrium condition does not require that all prices be equal, only that arbitrage drives the differences in prices net of transaction costs (the δ_{ij} terms) to zero.[8] After a shock, a new spatial equilibrium emerges, and conditions analogous to those specified will hold. For example, suppose a shock occurs in period t. Write the two periods' equilibrium conditions as:

$$P_{1t}^k = P_{2t}^k\left(1+\delta_2+v_2\right) = P_{3t}^k\left(1+\delta_3+v_3\right)\ldots = P_{nt}^k\left(1+\delta_n+v_n\right) \tag{3}$$

If the v terms are not zero, then not only have prices changed, but also the relationship among regional prices has changed between time $t-1$ and t. If Eq. 2 represents a spatial market equilibrium, adjusted for transport and other transaction costs, the v terms must tend toward zero to preserve the relationship among regional prices. Demonstrating that the v terms are not zero would be sufficient evidence to show markets are segmented.[9]

We now show how a test for market segmentation can be constructed by providing evidence that the v terms are not zero. As a first step, write Eq. 3 in logs:

$$\ln\left(P_{1t}^k\right) = \ln\left(P_{2t}^k\right) + \ln\left(1+\delta_2+v_2\right)\ldots = \ln\left(P_{nt}^k\right) + \ln\left(1+\delta_2+v_2\right) \tag{4}$$

where $\ln(\cdot)$ represents the natural log.

For sufficiently small δ_2 and v_2, the above is approximately equivalent to[10]:

$$\ln\left(P_{1t}^k\right) = \ln\left(P_{2t}^k\right) + \delta_2 + v_2\ldots\ln\left(P_{nt}^k\right) + \delta_n + v_n \tag{5}$$

Now, for exposition, consider prices in two regions. If the price relation between the two regions is the same in periods $t-1$ and t, the log differences will be equal. That is:

$$\ln\left(P_{1t-1}/P_{2t-1}\right) = \ln\left(P_{1t}/P_{2t}\right)$$
$$\Rightarrow \tag{6}$$
$$\ln\left(P_{1t}\right) - \ln\left(P_{1t-1}\right) = \ln\left(P_{2t}\right) - \ln\left(P_{2t-1}\right)$$

However, from Eqs. 2 and 5, we know:

$$\ln\left(P_{1t}\right) - \ln\left(P_{1t-1}\right) = \ln\left(P_{2t}\right) + \delta_2 + v_2 - \ln\left(P_{2t-1}\right) - \delta_2 \tag{7}$$

Saying the relative price relationship from time $t-1$ to t is stable is equivalent to saying that the log differences of the two prices are the same (Eq. 6). This, in turn, implies that the term v_2 in Eqs. 5 and 7 is zero. As noted above, if v_2 is not zero, then markets are segmented. We use the relationship in Eq. 6 to construct our test for segmentation.

OUR METHOD

We now construct an econometric test for market segmentation based on the relationships outlined above. We have shown that if log differences of two prices are equal, then relative prices do not change between the periods, and we have related this to the issue of market segmentation. Now specify a set of econometric equations. Suppose we specify two price equations in log differences and write each price equation as a function of some exogenous factor. For example, specify two regional prices as a function of some foreign price, P_f. For the moment, we suppress the other variables or lags of foreign prices for clarity:

$$\Delta\ln\left(P_1^k\right) = \beta_1 \Delta\ln\left(P_f^k\right) + \varepsilon_1 \tag{8}$$

$$\Delta \ln\left(P_2^k\right) = \beta_2 \Delta \ln\left(P_f^k\right) + \varepsilon_2 \tag{9}$$

where Δ represent first differences and ε_i are i.i.d. random errors.

Suppose further that the parameters β_1 and β_2 in Eqs. 8 and 9 are unequal. For example, suppose $\beta_1 = \beta_2\, a_2$. Then Eq. 8 becomes:

$$\ln\left(P_{1t}^k / P_{1t-1}^k\right) = \beta_2 \ln\left(P_{ft}^k / P_{ft-1}^k\right) + a_2 \cdot \ln\left(P_{ft}^k / P_{ft-1}^k\right) + \varepsilon_1 \tag{10}$$

Substituting from Eq. 9 into Eq. 10 yields:

$$\ln\left(P_{1t}^k / P_{1t-1}^k\right) = \ln\left(P_{2t}^k / P_{2t-1}^k\right) + a_2 \cdot \ln\left(P_{ft}^k / P_{ft-1}^k\right) + \varepsilon_1 - \varepsilon_2 \tag{11}$$

After taking expectations of both sides, Eq. 11 becomes:

$$\ln\left(P_{1t}^k / P_{1t-1}^k\right) = \ln P_{2t}^k /\left(P_{2t-1}^k\right) + a_2 \cdot \ln\left(P_{ft}^k / P_{ft-1}^k\right) \tag{12}$$

If $a_2 = 0$ then Eq. 12 collapses to:

$$\ln\left(P_{1t}^k / P_{1t-1}^k\right) = \ln\left(P_{2t}^k / P_{2t-1}^k\right) \tag{13}$$

which is algebraically equivalent to condition Eq. 6.

In summary, the condition in Eq. 6 holds if and only if a_2 is equal to zero, which is true only when the parameters β_1 and β_2 of Eqs. 8 and 9 are equal. Because this is equivalent to v_i being zero, these relations suggest a method for testing for market segmentation: Specify the difference of logged prices in each domestic region as a function of exogenous factors. Then test whether the coefficient, which measures the transmission of outside information to regional markets, is the same for every region. If this coefficient is significantly different, then a necessary condition for market integration, stability of market price relationships, is not met. This is sufficient to show that markets are segmented.

Putting the Method to Use

To make the test more general, suppose log price difference equations such as Eqs. 8 and 9 are jointly specified for M, rather than two, regional markets. Furthermore, suppose CPI and seasonal terms are added to each equation, in addition to the foreign price. To test for segmentation of Russian beef and pork markets, we proceed as follows.

First, for each of M markets in Russia, we specify the log price difference equations for each meat product as:

$$\Delta \ln P_{it} = \sum_{n=0}^{4} \beta_{i1n} \Delta \ln\left(FP_{t-n}\right) + \sum_{n=0}^{4} \beta_{i2n} \Delta \ln\left(CPI_{t-n}\right) + \sum_{n=0}^{4} \beta_{i3n} DM \cdot \Delta \ln\left(FP_{t-n}\right)$$
$$+ \sum_{j} \theta_{ij} TSEA + u_i \tag{14}$$

for regions $i = 1, \ldots, m$; lags $n = 1, \ldots, 4$; seasonal effects $j = 1, 2$

where:

FP = the foreign price

CPI = the Russian CPI (lags of the *CPI* and *FP* are discussed later)

DM = a dummy variable, which is zero before the crisis and one after

TSEA = harmonic trigonometric variables used to capture seasonal changes in prices (these are defined as: $\sin = \text{sine}((j/6)\pi t)$ and $\cos = \text{cosine}((j/6)\pi t)$, where t is the observation number, i is the city observation, and $j = 1$). Thus one annual cycle per year is modeled. In order to keep the model simple, higher frequency cycles are not included.

u_i = the error in Eq. 14.

We then jointly estimate Eq. 14 for different city observations in a Seemingly Unrelated Regression (SUR) system of equations. To test whether the foreign price (or CPI) transmits equally to different cities, the restriction that the coefficient β_{i1} (or β_{i2}) is equal across equations is imposed. If the β_{i1} are equal across all M market equations, this is equivalent to stating all v_i are zero — otherwise, some v_i are not zero and markets are segmented.

A system log likelihood ratio test can be used to determine if this restriction can be rejected (see Greene 1993, 497). If the transmission from the foreign price (or CPI) is not equal among city markets in the region, the cross equation restriction will significantly reduce the fit of the system. This is equivalent to saying at least one v_i in the system is not zero and that there is segmentation in the markets being tested. If the restriction does not significantly reduce the fit of the system, the foreign price (or CPI) transmission are not significantly different from that of each region's city markets. In this case, markets are either integrated, or segmented with coincidentally equal foreign price (or CPI) transmissions (Ravallion 1986).

The complete transmission from foreign prices (or the CPI) to retail prices may take time, so we specify our model to have an impact effect and four months of lagged effects. Though testing procedures for optimal lag lengths are available (Greene 1993, 515), they may result in different lag lengths for different equations. Therefore, we set a standard lag length for all equations. Later, we show that Box-Pierce Q tests on the residuals of the equations reveal that the errors of most of the beef and pork equations are white noise, indicating that the lag length and our representation of seasonality are adequate.

We test the equality of foreign price transmission to Russia's city markets up to lag n by testing the following restriction for region j:

$$\sum_{i=0}^{n}\left(\beta_{1li}\right) = \sum_{i=0}^{n}\left(\beta_{2li}\right)\ldots = \sum_{i=0}^{n}\left(\beta_{mli}\right) \tag{15}$$

To test for equality of foreign price transmission after the crisis, we test:

$$\sum_{i=0}^{n}\left(\beta_{1li}+\beta_{13i}\right) = \sum_{i=0}^{n}\left(\beta_{2li}+\beta_{23i}\right)\ldots = \sum_{i=0}^{n}\left(\beta_{mli}+\beta_{m3i}\right) \tag{16}$$

Finally, to test if the crisis had no effect on price transmission, we test:

$$\beta_{i3n} = 0 \qquad\qquad (17)$$

for every region i and for every lag n.

One advantage of the above approach for testing market segmentation is that it is possible to test for any combination of regional prices contained in the system of equations. For example, in this paper, we later test whether markets in net importing regions have significantly different transmissions from those of net exporting regions.

Another advantage of the approach is that it allows for the testing of equality of transmissions for as many exogenous variables as the equation specification allows. For example, by including the CPI as an explanatory variable, not only can we test for equality of foreign price transmissions, but also we can use similar restrictions to test the equality of CPI transmissions from the same set of equations.

Several items concerning this test should be noted. The test rests on the assumption that foreign price changes transmit at least part way to at least one market. In the results section, we show that this assumption holds. Second, it is important to distinguish between domestic-to-international market integration and integration **within** the domestic market. While the magnitude of the price transmission coefficients from international to domestic markets (the β_i) measures international integration, it is the variability of transmission parameters (the variation in β_i) among regional markets that is related to domestic market segmentation, the focus of this paper. Third, by jointly evaluating the response of many city markets to a single exogenous shock, we avoid testing all possible bilateral price relationships among all city markets. This has the advantage of being parsimonious in the use of data and computational power. Such a test is ideally suited to data sets that contain a large number of cross-sectional observations but not a long time series dimension.

Comparison with Other Tests

It is worth comparing our method to two other methods of testing market integration. Ravallion's (1986) market integration test also specifies a system of market transmission equations. However, Ravallion's exogenous price was part of the market he was testing, while in our case the foreign price is truly exogenous to Russia. Also, while Ravallion tested if transmission coefficients across regions together equaled a particular number, we do not impose *a priori* what the transmission parameters should be. We test only for consistency of transmission across markets.

Our test for short-run market segmentation can be considered a complementary tool to the Johansen and Juselius (1990) cointegration test. While the error corrections model of the Johansen-Juselius test can be used to examine short-run market integration, it requires that long-run cointegrating relationships be established first. We are interested in testing for short-run market segmentation without having to assume long-run integration, which may not have existed in the chaotic transition period in Russia.

Furthermore, testing for long-run integration in Russia with the Johansen-Juselius technique would encounter two significant problems. First, there are a large number of structural breaks in the price relationships, caused by economic crises, relative to the length of the time series. Since a nonstationary series consists essentially of a stationary series plus a new, unpredictable structural break each time period, it is difficult statistically to distinguish a cointegrated relationship with a large number of structural breaks from a truly noncointe-

grated relationship. Another problem is introduced by the large size of the cross-sectional component of the data relative to the length of the time series. The Johansen-Juselius test loses a degree of freedom in each equation for every market added. When applied to our data, a Johansen-Juselius test would run out of degrees of freedom before all of the cities in the Russian cross section could be included. Therefore our method may be better suited to the transitional economy of Russia, where the time series data is interrupted by a large number of structural breaks and the number of cross sections is large relative to the length of the time series.

DATA

We use a series of monthly retail prices of beef and pork for markets in 80 Russian cities (the capitals of the 80 oblasts, republics and autonomous districts that make up Russia). The data period ran from January 1994 to September 1999. We use monthly prices since we want to evaluate market response within a year and monthly prices are the highest frequency data available. We convert the foreign price into rubles to avoid having to specify and test yet another variable (the exchange rate). So we test for a combination of foreign price transmission and the transmission of changes in the real exchange rate.[11]

The domestic prices of beef and pork are provided by the Ministry of Agriculture of the Russian Federation. The international pork price was a low-priced retail pork price (shoulders) from the USDA/ERS. This price is chosen to reflect the relatively low price of pork imported by Russia. The international beef price was the wholesale price of U.S. choice yield grade 3, a price that tends to dominate world beef markets. The data from all variables are stationary once transformed to the difference log form as specified by our model.

The Russian data set is quite large, and joint testing requires specification of an equation for every city. Even with our method, testing all Russian cities in the data set jointly for equality of price transmissions would be too broad a test, particularly because finding segmentation in a subregion is sufficient to prove segmentation for the nation as a whole. Therefore we break the data into subregions, approximately the same as those used by Russia's Statistical Service, (Goskomstat): North, Central, Black Earth, Caucus, Volga Valley, Urals, West Siberia, East Siberia and the Far East. The cities within each region are similar in terms of their distance to international markets and their physical infrastructure. We then test whether foreign price transmissions are equal in each region by estimating one system of price transmission equations for all city markets in that region. We do this in turn for each of the subregions.

RESULTS

As noted earlier, the model specification requires that the exogenous prices, the foreign price and the CPI, be in log differences. This specification insures that all our data are stationary so that our test statistics are not distorted by using nonstationary data. For nine separate regions within Russia, we estimate a system of price transmissions equations. Because the markets for Moscow and St. Petersburg are significantly different in terms of access to international markets and physical infrastructure (inherited from the Soviet Union), we remove them from the estimation so as not to bias the test toward finding segmentation. Each price transmission equation in a regional system represents one city inside the region. Each system is estimated with and without the restriction that imposes the equality of foreign price transmissions across all markets in the region. In almost every equation, both the exogenous foreign price variable and the Russian CPI is significant for at least one of the lags. The sea-

sonality variables are significant in approximately half of the equations. Box-Pierce Q tests are preformed on the errors of each equation (see Table 1) and show that the errors of over 90% of both pork and beef price transmission equations are white noise.

Different price transmission restrictions are imposed at different lags. The first test imposes the equality of the sum of foreign price transmissions across all four lags. This restriction gives regions four months to eliminate city market differences in initial transmission rates. Then we test for equality of transmission over the sum of three lags, then two lags, and so on.[12] In the most restrictive test, equality of transmission is imposed at impact. We evaluate the feasibility of these restrictions for each region using a systems log likelihood ratio test.[13] We apply the same set of tests to the CPI transmission coefficients in each regional market.

Tables 1 and 2 report several items pertaining to the price transmission equation. The table reports the percentage of each region's markets where the foreign price transmission (over all lags) are significantly different from zero, the average price transmission in each region, the variance of price transmissions in each region, and provides two diagnostic statistics for the equation from each region. Our market integration rests on the assumption that at least one regional market price transmission is greater than zero. The first row in Table 1 shows that for pork this assumption holds for every commodity and in every region before the crisis, and in all regions but the Caucus for pork after the crisis. The first row in Table 2 shows that for beef this holds for every commodity in every region before and after the crisis.

Tables 1 and 2 show that the average regional transmission fell after the crisis. To average transmission for a particular region, each market's total price transmission is calculated by summing over all lags. Then the price transmissions of each market are averaged over the region. The falling price transmission indicates that the degree of integration with international meat prices fell after the crisis. Tables 1 and 2 also report the variance of price transmissions among markets before and after the crisis. A higher variance indicates wider regional market variation of price response to a change in foreign prices and suggests that a region's markets may not be integrated.

Tables 1 and 2 also provide a pseudo R^2 and report on our tests for white noise residuals in each equation. A traditional R^2 cannot be measured because the constant term is suppressed (it would represent an unnecessary drift term). Instead, we regress the endogenous variables on their predicted values and a constant to obtain an R^2 from that estimation. Both tables report the percentage of equations in each regional system where the error terms are found to be white noise. The Box-Pierce Q test is used to determine whether the errors in each equation where there is white noise. If errors are white noise, the addition of new variables or lags on existing variables will not improve the equation specification.

Tables 3, 4 and 5 present the results of testing for equality of foreign price and CPI transmission among city markets within each region. Each table presents χ^2 statistics obtained from applying a log likelihood ratio test for equality of transmission coefficients in each region's city markets. The tests are applied across all lags, then for the first three lags, etc., and then only at impact. Unequal price transmissions are evidence of market segmentation as explained in the Market Price Relationships and Segmentation section.

The χ^2 test statistics in Tables 3 and 4 show that, in most regions, there is evidence of market segmentation for both pork and beef for at least two months after a foreign price change. Furthermore, in the Volga Valley, Urals, West Siberia and Far East regions, evidence

Table 1. Average and variance of foreign pork price transmissions within regions

								Region
	North	Central	Black Earth	Volga Valley	Caucus	Urals	West Siberia	East Siberia	Far East
Before the crisis:[a]									
% significance[b]	25	42	50	33	60	80	50	20	20
Average[c]	0.51	0.70	0.89	0.65	0.63	0.75	0.73	0.17	0.45
Variance[d]	0.18	0.05	0.10	0.20	0.05	0.16	0.17	0.10	0.15
After the crisis:[a]									
% significance[b]	25	25	12.5	16.5	0	40	40	0	20
Average[c]	0.03	0.16	0.23	0.07	–0.06	0.23	0.20	0.06	0.09
Variance[d]	0.03	0.02	0.05	0.09	0.01	0.05	0.05	0.01	0.02
White noise %[e]	75	91.6	100	83.3	100	100	100	60	100
$R^{2\,f}$	0.53	0.68	0.62	0.86	0.68	0.85	0.82	0.71	0.29

[a]The August 1998 Russian financial crisis.
[b]Indicates the percentage of cities in each region where a zero price transmission (PT) restriction is rejected.
[c]The average PT among a region's city markets. A PT of one represents perfect price transmission, while a PT of zero represents zero price transmission.
[d]The variance of PT among a region's city markets; a higher variance indicates the markets within a region respond unevenly to an outside price change.
[e]A system of price transmission equations, representing the markets in each region, is estimated for every region. White noise % represents the percentage of the equations (in each regional system) where the Box-Pierce Q test indicates the equation errors are white noise.
[f]The equations do not include a constant term, so R^2 is calculated from a regression of the dependent variables against the predicted values and a constant.

of segmentation extends out as far as four months (for pork). There also is an indication that pork prices in the North and the Black Earth regions were segmented out to the four-month lag following the financial crisis.

For beef, there is more regional variation than for pork. There are three regions that show evidence of market segmentation out to three or four months before and after the crisis (the North, Central and Volga Valley regions), while four regions show relatively little evidence of segmentation (the Black Earth, Caucus, Urals and East Siberian regions).

The tests for CPI transmission for pork show evidence of segmentation out to three months for all regions except the Far East. The CPI transmission results for beef again show regional variation, with the Central, Volga Valley and West Siberian regions showing segmentation out to the third lag, while the Caucus, Urals and the Far East regions display little evidence of segmentation.

Other Tests

As noted earlier, the advantage of our system test is that equations can be grouped into any subsystem the modeler chooses. We set up a system of equations that represented regions that

Table 2. Average and variance of foreign beef price transmissions within regions[a]

| | | | | | Region | | | | |
	North	Central	Black Earth	Volga Valley	Caucus	Urals	West Siberia	East Siberia	Far East
Before the crisis:									
% significance[a]	100	69	60	29	14	80	100	0	33
Average[b]	0.48	0.40	0.50	0.28	0.30	0.31	0.27	0.24	0.33
Variance	0.01	0.07	0.31	0.04	0.05	0.03	0.15	0.00	0.36
After the crisis:									
% significance[a]	85	53	20	29	28	80	100	0	17
Average[b]	0.32	0.25	0.01	0.21	0.15	0.34	0.32	0.16	0.24
Variance	0.01	0.02	0.21	0.01	0.01	0.01	0.01	0.01	0.09
White noise %	100	83.4	100	100	100	100	87.7	100	100
R^2	0.79	0.63	0.72	0.62	0.74	0.60	0.62	0.42	0.73

[a]See notes to Table 1 for definitions.

export and import beef and pork to and from other Russian regions. We use a system log likelihood ratio test to ascertain whether the price transmissions were similar for exporters and importers. We jointly test for similar exporter/importer transmissions at all lags. We also test whether the sum of the transmission coefficients over all lags of exporters equals the sum of the importer transmission coefficients over all lags. To do this, we set up a test that is the least likely to reject equal transmission for importers and exporters. That is, we test whether importer and exporter transmissions differ, while forcing, through coefficient restrictions, all exporters to have equal transmissions and all importers to have equal transmissions. This restriction is compared with a system where all coefficients, both importer and exporter, are equal. The χ^2 statistic from the log likelihood ratio test rejects equal foreign price transmissions for importers and exporters at the 95% confidence level for pork, but not for beef markets. These results hold both before and after the financial crisis.

Crisis Dummy Variable
Earlier we argued that the 1998 financial crisis in Russia may have an influence on integration of the Russian food market and provided several competing explanations what this influence might be. Driving regions toward less integration were food security concerns that led regional administrators to restrict trade. Driving toward more integration was the fact that consuming regions substituted domestic meat for imported meat after the ruble's devaluation.

Because of the decline in foreign imports, the crisis could have altered the relative price transmission coefficients between two markets even when markets were not segmented. For example, in the case where two domestic markets import from abroad, they could initially have had a price difference that was determined by the difference in transaction costs of importing to one city versus the transaction costs of importing to the other city. If one domestic market switched from importing from abroad to importing from the other domestic market, then their

Table 3. χ^2 statistics: Test for equality of pork price transmissions within regions[a]

					Region				
	North	Central	Black Earth	Volga Valley	Caucus	Urals	West Siberia	East Siberia	Far East
Degrees of freedom[b]	3	11	4	5	4	5	9	4	4
Before the crisis:									
Impact[c]	*16.2	*66.1	*48.9	*37.6	*27.4	*12.6	*33.9	*13.8	*20.1
1 lag	*15.6	*53.1	*20.9	*24.6	*23.8	9.3	*32.0	*26.3	*13.3
2 lag	*11.4	*20.4	*13.4	*23.1	9.1	*18.1	*37.2	*13.0	*10.0
3 lag	6.2	16.2	10.8	*17.8	1.7	*14.9	*22.2	8.0	*13.6
All lags	6.2	10.9	8.6	*11.6	2.8	*13.1	*21.9	8.0	*11.8
After the crisis:									
Impact[c]	*12.2	*31.5	*16.8	*15.3	2.6	5.7	*25.0	5.4	*10.6
1 lag	*37.8	*31.7	*22.2	3.1	*14.4	*13.5	*34.9	9.1	3.4
2 lag	*27.8	*25.4	*41.4	*50.8	*14.4	*25.3	*29.4	*15.2	4.0
3 lag	1.0	17.4	*13.6	*18.6	7.0	*15.3	11.0	7.8	*10.8
All lags	*11.8	10.3	*15.0	*15.8	7.8	*16.6	*20.0	4.5	7.8

[a]A system of price transmission equations, representing the markets in each region, is estimated for every region. The statistics reported are from the system log likelihood test. This test compares a model that restricts price transmissions to each city in the region to be equal against an unrestricted model.
[b]Tests whether price transmissions are the same at impact or monthly lags. "One lag," "2 lag," etc. tests whether transmissions are the same after 1 lag, 2 lags etc. We test the restriction that the sum of transmission coefficients (at impact, and up to lag i) are equal. For example, "2 lag" reports χ^2 statistics from a test where the sum of the PT coefficients at impact, first lag and second lag is set equal in city markets. This is tested against an unrestricted model.
[c]Each regional test has different degrees of freedom, since each region has a distinct number of city markets to test. For example, the difference in the degrees of freedom explain while the number 11.8 is significant in the North region but 17.4 is not significant in the in the Central region.
*Indicates that the χ^2 statistic is significant, meaning the hypothesis that price transmission to all city markets within a region are equal can be rejected at the 0.05 confidence level.

price difference would be determined by the transaction cost of shipping between the domestic markets. This would change the coefficient on that market's foreign price transmissions. Therefore, it is essential to include a crisis dummy in the estimated equations, since the only time such a situation occurred was after the crisis when meat imports fell significantly.

An interaction dummy variable is included, at each lag, on the foreign price variable in every transmission equation. The dummy variable is set equal to zero before the crisis and one afterward (the crisis being marked by Russia's default on domestically issued debt in August 1998). As with our other tests, we use a systems log likelihood ratio to evaluate the joint significance of the dummy variable across the system of equations. We apply this test at impact and at each of four monthly lags.[14] The results of the dummy variable tests are pro-

Table 4. χ^2 statistics: test for equality of beef price transmissions within regions[a]

					Region				
	North	Central	Black Earth	Volga Valley	Caucus	Urals	West Siberia	East Siberia	Far East
Degrees of freedom	6	12	4	6	6	4	8	3	5
Before the crisis:									
Impact	*20.8	*33.0	4.8	5.6	5.8	*18.1	*34.9	7.1	*31.7
1 lag	*30.0	19.8	4.2	*21.1	5.3	7.2	*23.6	2.1	*29.1
2 lag	*23.4	*37.9	8.9	*28.1	*12.8	8.7	*17.0	2.3	*25.1
3 lag	*21.2	*25.4	2.7	*14.7	6.3	*11.8	13.6	5.4	10.3
All lags	11.7	*24.6	2.0	*14.7	11.2	5.6	9.0	7.3	9.2
After the crisis:									
Impact	*68.8	*52.6	5.8	*25.4	*14.0	4.2	*43.1	* 9.8	*15.6
1 lag	*46.5	*34.3	*11.7	*15.1	*20.4	1.1	10.8	4.1	*11.6
2 lag	*58.9	*32.7	6.9	*15.3	*13.8	2.2	*45.7	5.8	9.8
3 lag	*25.6	*45.1	*12.8	*17.6	*12.9	*10.5	*26.5	*28.9	6.6
All lags	*13.8	*23.2	3.2	6.6	4.6	3.2	6.0	0.3	3.1

[a]See notes to Table 3 for definitions.

vided in Table 6, which shows that the dummy variables are significant at the 1% level in all the regions for all lags.

Comparing the size of the foreign price transmission elasticities in the pork market before and after the crisis, we find that the average foreign price transmission elasticity was lower after the crisis (when summed across all lags) in all regions (see Table 1). The significance of this variable shows that Russia's domestic markets were less integrated with international markets after the crisis. However, it does not say whether domestic markets were more or less segmented. Comparing the variability of foreign price transmission elasticities before and after the crisis, we find mixed results. The χ^2 test for equality of price transmissions in Table 3 before and after the crisis reflects this. When the dummy variable is included in the foreign price transmission equality tests, it shows that market segmentation increased in some regions, like the North and Black Earth regions, while in other regions such as East Siberia, there is less evidence of segmentation. As suggested in the discussion above, there is no clear *a priori* argument about what the effect of the crisis would be on the variability of foreign price transmission and market segmentation, and the results bear this out.

Comparing the size of beef foreign price transmission elasticities (summed across all lags), it is clear that the average foreign price transmission elasticities fell after the crisis, except in the Urals and West Siberia (see Table 1). Comparing the variability of beef foreign price transmission elasticities, we also find mixed results. The χ^2 test for equality of price transmissions in Table 3 before and after the crisis provides evidence of more market segmentation in beef markets in North, Caucus and East Siberian regions after the crisis.

Table 5. χ^2 statistics test for equality of CPI price transmissions within regions[a]

					Region				
	North	Central	Black Earth	Volga Valley	Caucus	Urals	West Siberia	East Siberia	Far East
Pork:									
Degrees of freedom	3	11	6	5	4	5	9	4	4
Impact	6.4	*20.7	*13.5	*18.0	1.5	*17.2	*29.4	4.3	*14.5
1 lag	*36.6	*33.6	*27.8	*12.2	*15.3	5.5	*32.7	6.5	3.8
2 lag	*30.3	*32.5	*41.1	*52.6	*22.7	*43.2	*46.8	*26.5	2.5
3 lag	*16.3	*29.9	*35.0	*38.4	7.2	*34.7	*24.0	* 9.9	6.4
All lags	* 9.5	10.2	10.4	*14.1	2.0	*14.5	*18.3	8.0	7.3
Beef:									
Degrees of freedom	6	12	4	6	6	4	8	3	5
Impact	3.3	*29.3	4.9	*16.1	*12.6	3.4	*36.5	*17.9	7.3
1 lag	2.9	19.3	6.3	9.5	10.2	2.9	10.9	5.3	11.0
2 lag	*43.9	*35.0	*12.3	*28.8	7.6	4.5	*35.6	1.3	*12.8
3 lag	*16.4	*46.0	*15.9	*18.2	8.5	9.5	*20.5	* 9.2	7.9
All lags	9.9	*28.7	2.7	10.3	6.6	1.5	8.4	3.9	2.2

[a]See notes to Table 3 for definitions.

CONCLUSION

Our tests show that changes in world prices do not transmit fully to domestic markets in Russia until after a lag of about two months. More importantly, the tests provide evidence that prices are transmitted unevenly, with prices in some cities absorbing shocks in world prices more quickly than others. We conclude that there are significant barriers in some regional markets that prevent rapid transmission of prices from one region to another and that, in the short run, the Russian domestic meat market was segmented over the period of analysis. We do not take a stand on the mixed findings of numerous studies that deal with the separate issue of long-run market integration across Russia. We do claim that even if Russian markets are found to be integrated in the long run, short-run distortions existed.

The evidence is mixed about the effect of the financial crisis on market segmentation, with some regions showing more evidence of segmentation, while others may have become less segmented.

Our study's goal is to determine whether Russian regional markets showed any signs of short-run segmented. A logical follow-up question is why the markets might be short-run segmentation. There are two possible two reasons. One is that regional authorities had imposed policy barriers to prevent the export of food products to food deficit regions. The other reason for market segmentation is the poor physical infrastructure and risk associated with doing business in Russia. This second phenomenon should be more economy-wide. Since we find

Table 6. The financial crisis dummy variable[a]

	Region								
	North	Central	Black Earth	Volga Valley	Caucus	Urals	West Siberia	East Siberia	Far East
Degrees of freedom	20	60	35	30	25	30	50	25	25
χ^2 pork	90.4	182.4	561.5	157.0	72.5	96.0	172.1	88.6	57.3
χ^2 beef	222.1	205.2	70.5	121.8	81.1	56.3	130.1	53.2	86.2

[a]The system that includes dummy-price interaction variables is compared with the system with no dummy variables. All χ^2 statistics are significant at the 1% level, rejecting the model without dummy variables.

that uneven price transmission between markets characterizes the entire geographical area of Russia, we are inclined to believe that physical infrastructure and institutional problems dominate the problems caused by regional trade policy. The findings in this paper should encourage additional studies that focus exclusively on the related issue of why markets in the nascent Russian market may be segmented.

The findings of this paper should also remind economists that other countries or regions that have been shown to be integrated in the long run, may still be segmented in the short run.

NOTES

[1]Russia is a meat importer primarily because the livestock sector collapsed after reforms when subsidies to production were reduced. For more information, see Cochrane et al (2002).

[2]While livestock production is slow to respond to price change, there appeared to be little response even after several quarters.

[3]Besides physical infrastructure lack of a capital market, poor market information and weak legal infrastructure/corruption hinder market integration. Economic institutions include commercial law that protects property and enforces contracts, a regulatory system that significantly reduces corruption, and a system of market information (Wehrheim et al 2000).

[4]Following the devaluation, food imports fell significantly. According to Russians Customs statistics, imports of HS codes 1–24 (produce and agricultural materials) in the third and fourth quarter of 1998 was 66% and 48% of the previous year's value.

[5]They also found that prices in state-owned stores were Granger-caused by prices in private stores.

[6]Li faults traditional integration studies for excluding the influence of factors such as the CPI and seasonality.

[7]We justify representing transactions costs as percentage changes in the good's price because the major transaction cost is the risk associated with lost output in shipment due to waste or theft (particularly in Russia).

[8]We assume the existence of trade flows that force the price differences to be exactly equal to transaction costs. Russia's imports of pork and beef, the commodities analyzed in this study, provides the trade to force equality.

[9]When a market moves from trading with an outside source (Eq. 2) to trading internally (Eq. 1), regional price relationships can alter. This would apply to Russia during the crisis. Our model includes variables to account for this.

[10]This comes from the well established relationship that Ln $(1 + a + b) \approx a + b$, for small a and b.

[11]Algebraic manipulation of the law of one price shows that the real exchange rate transmission on real prices should be one. For the sake of this paper, we assume the real exchange rate transmission is one.

[12]Here, specific lagged coefficients can be different. This restriction requires only that the price transmissions among regions are equal after the number of specified lags are summed.

[13]We also use a system log likelihood ratio test to determine the joint significance, over all lags, of each market's foreign price transmission coefficients (testing in turn each equation in every regional system). This test determines whether the passthrough in a specific market is significantly different from zero.

[14]Coefficients and t-statistics on the foreign price, CPI and dummy interaction variables of all equations can be provided upon request.

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APPENDIX

This appendix describes the relationship among price for cities that lie along a "rail line" from an originating city. It then shows how prices between cities that do not trade with each other (they are on rail lines that have only the originating city in common) are related.

Assumption: Among the set of n cities, for each city , there exists at least one subset of m cities, $m \leq n$, and an ordering $j = 1, \ldots, m$ such that the originating city is first in the ordering, the last city is city , , and for all j, $q_{j,j+1} > 0$.

Call the subset of cities that satisfy this requirement for city , the "rail line" of city ,. Let the cost of shipping from city j to $j + 1$ be c_{j+1}. If costs are additive, the cost of shipping to city , is $\sum_{i=1}^{L} c_j$.

If instead costs are better expressed as a percentage of the purchase price (i.e., $P_j \cdot c_j$), the relationship between prices in adjacent cities in the ordering can be expressed as $P_j = P_{j+1}(1 + c_{j+1})$, and the relationship between the prices in city , and the originating city can be expressed as:

$$P_1 = P_\ell \cdot \prod_{j=1}^{\ell} \left(1 + c_j\right) \tag{A-1}$$

It is possible for different cities to be on (almost) disjoint rail lines, so that their rail lines have only the originating city in common. For these cities the price relationship between them can be derived through their relationship with the originating city. For example, we note that for city , there exists a

subset m that has the following relationship with the originating city:

$$P_1 = P_\ell \cdot \prod_{j=1}^{m}\left(1+c_j\right) \tag{A-2}$$

Consider a city r, for which there are no rail lines connecting it to city $_,$. Let $m*$ be a subset that is a rail line connecting city r to the originating city. The price relationship between the originating city and city r is:

$$P_1 = P_r \cdot \prod_{s=1}^{m*}\left(1+c_s\right) \tag{A-3}$$

It is clear that even when cities do not trade with each other the prices are related. For example, the relationship between city r and $_,$ can be derived as:

$$P_r = P_\ell \cdot \left(\prod_{j=1}^{m}\left(1+c_j\right)\right) / \prod_{s=1}^{m*}\left(1+c_s\right) \tag{A-4}$$

It should be clear that these c_j's are embodied in the δ terms of Eq. 2 of the text.

Finally, it is possible to construct assumptions that do not require all information to pass through one city in order for all cities to receive the same information (e.g., for all city pairs there is a rail line that connects them). The originating city concept is likely to be a reasonable description of the situation in the regions of Russia and most developing countries.